

PHORIDAE (DIPTERA) ASSOCIATED WITH CULTIVATED
MUSHROOMS IN EASTERN NORTH AMERICA

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Abstract.—*Megaselia (M.) halterata* (Wood) is the most widespread and important pest of cultivated mushrooms in the U.S. The larvae of this phorid infest the mushroom beds and feed on the developing mycelium. In the U.S., six *Megaselia* species have been reported as pests of cultivated mushrooms. A review of the history and taxonomy of these species, however, indicates that only one, *M. halterata*, is the dominant pest at this time. Accurate identification of the phorids commonly associated with cultivated mushrooms is facilitated by the accompanying figures of the male and female terminalia. Although one mushroom phorid is dominant in the U.S. at this time, the expansion of the mushroom industry to other parts of the world increases the possibility of new pest phorids.

Phorid flies are the most widespread and perhaps the most important pests of cultivated mushrooms. Several species in the genus *Megaselia* have been reported attacking cultivated mushrooms in the U.S. and western Europe. Larvae of some species feed on and destroy the mushroom mycelium, while larvae of other species feed on the fruiting bodies. Adult phorids are pests because of the large number that invade mushroom houses, and their potential as vectors of mushroom-disease pathogens. The adults may also be a nuisance by invading private homes in areas adjacent to mushroom farms.

The substantial commercial value of cultivated mushrooms in the U.S. and other countries has prompted investigations of their pest fauna. Workers in western Europe have identified three *Megaselia* species as pests of cultivated mushrooms: *Megaselia halterata* (Wood), *M. nigra* (Meigen), and *M. bovista* (Gimmerthal). However, only *M. halterata* is a consistent economic pest at this time. In the U.S., six *Megaselia* species have been implicated as mushroom pests. But only one species is dominant. This species has been known under a variety of names: *Megaselia agarici* (Lintner), *M. bovista*, *M. halterata*, and *M. dakotensis* (Borgmeier).

The objectives of this paper are to review the taxonomy and history of the *Megaselia* species reported attacking cultivated mushrooms, to elucidate which species is currently the primary pest in mushroom houses in eastern U.S., and to provide diagnostic characters for identifying the *Megaselia* species associated with cultivated mushrooms in the U.S.

A review of the historical development of cultivated-mushroom entomology was provided by Hussey (1972). Some of the significant papers on the

taxonomy and biology of phorids infesting cultivated mushroom include Thomas (1942), Schmitz (1948), Colyer (1954, 1956), Hussey (1959, 1960), Borgmeier (1967), and Robinson (1975). Recent papers on the control of mushroom pests include Hussey and Hughes (1964), Hussey (1965, 1969), Hussey et al. (1969), Wyatt (1969), Parsells (1974), and Spencer (1976).

Material and Methods

Centers of commercial mushroom production in eastern U.S., both past and present, were visited and surveyed for phorids. Mushroom farms in New York, Pennsylvania, Delaware, and Virginia were surveyed in 1973–76. Museum specimens from Michigan, South Dakota, and California were also examined.

The British Museum (Natural History) supplied specimens of *Megaselia bovista*. Specimens of *M. halterata* were provided by Dr. E. S. Binns of the Glasshouse Crops Research Institute. Type-material of several *Megaselia* species was examined at the U.S. National Museum, and the New York State Museum.

Voucher specimens were deposited in the collection of the U.S. National Museum and in the Insect Collection, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg.

Taxonomy and History of Mushroom Phorids

Although several *Megaselia* species have been reported attacking cultivated mushrooms in the U.S., not all of the reports are accurate and some of the species are no longer serious pests. A review of the taxonomy and the association which these species have had with cultivated mushrooms may help eliminate some of the confusion.

Megaselia (Megaselia) nigra (Meigen) (Figs. 2, 3, 10)

Synonymy: *Phora albidihalteris* Felt, 1898; *Aphiochaeta albidihalteris* Felt. Popenoe, 1912; *Aphiochaeta smithii* Brues. Thomas, 1939.

Diagnosis.—This species can be distinguished from other North American *Megaselia* by the combination: Mesanepisternum bare; scutellum with 2 strong bristles, costa about 0.46% (rarely 0.42%) of wing length; halteres yellow; hind tibia of male flattened on apical $\frac{1}{3}$. Hypopygium with epandrium (Fig. 2) with 6–9 strong bristles; hypandrium (Fig. 3) with a hooked process at apex of left lobe. Oviscapt with sternum 6 (Fig. 10) clavate, and with 6–7 bristles.

Known Distribution.—Europe, North America.

Larval Biology.—The larvae tunnel in the stems and caps of mushrooms.

Remarks.—This phorid has been reported attacking cultivated mushrooms in Europe and North America. The first reports of *M. nigra* associated with mushrooms were Dufour (1841), and Scholtz (1849) in western Europe. Moreton (1954) and Hussey (1959, 1961) reviewed the biology of this fly.

Megaselia nigra was the most important fly pest of cultivated mushrooms in western Europe until the early 1950's. At that time *M. halterata* emerged as the dominant phorid pest. The reports of Felt (1898), Popenoe (1912), and Thomas (1931) indicate that *M. nigra* (as *Phora albidihalteris*) was also a pest of the mushroom industry in the U.S. It was considered a pest of cultivated mushrooms in the U.S. until about the early 1940's. At that time *M. agarici* emerged as the dominant pest.

Hussey (1959) found that *M. nigra* will lay eggs only where natural light falls on mushroom beds. In most commercial farms damage occurred only near the doors of the mushroom houses. More efficient ventilation systems which enable the doors of the mushroom houses to remain shut have practically eliminated this species as a pest. *Megaselia nigra* is not now a serious pest of cultivated mushrooms in Europe or the U.S.

Megaselia (Megaselia) bovista (Gimmerthal)
(Figs. 6, 7)

Synonymy: *Phora bovista* Gimmerthal, 1848.

Diagnosis.—This species can be distinguished from other North American *Megaselia* by the combination: Mesanepisternum bare; scutellum with 2 strong bristles; costa 0.36–0.44% of wing length; halteres yellow; dorsal row of setae on hind tibia sharply deflected. Hypopygium with epandrium (Fig. 6) without strong bristles; hypandrium (Fig. 7) with large setose lobe.

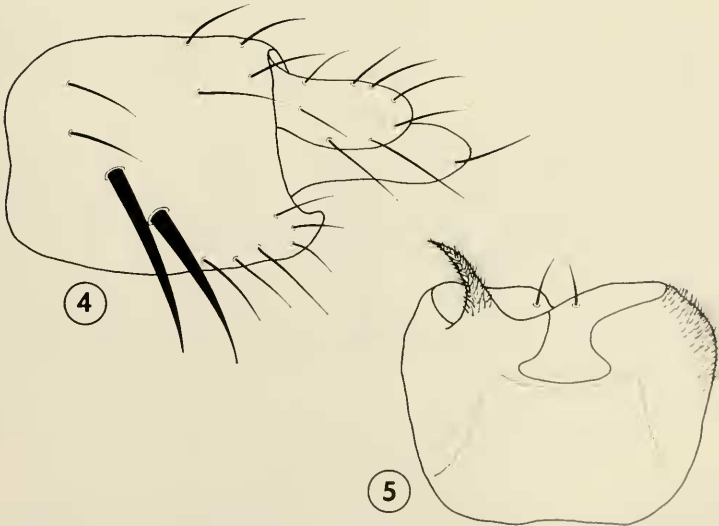
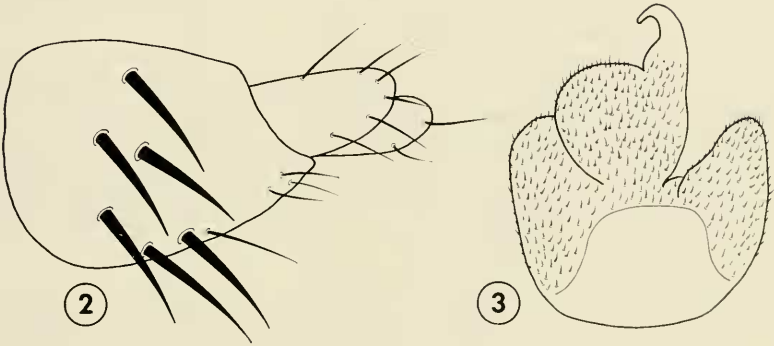
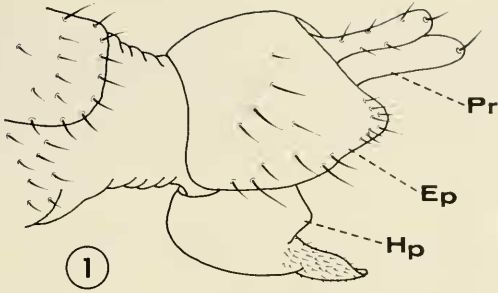
Known Distribution.—Europe.

Larval Biology.—The larvae tunnel in the stems and caps of mushrooms.

Remarks.—This species is usually presented as one of the three most important phorid pests of cultivated mushrooms in western Europe. (The other species are *M. nigra* and *M. halterata*.) However, *M. bovista*'s reputation as a pest is based on a single outbreak in Staffordshire, England in 1953 (Colyer, 1956). It is an uncommon to almost rare phorid in cultivated mushroom houses in England at this time (E. S. Binns, personal com-

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Figs. 1–5. *Megaselia* spp. male genitalia. 1, *Megaselia* sp., male hypopygium. 2, *M. nigra*, epandrium. 3, *M. nigra*, hypandrium. 4, *M. halterata*, epandrium. 5, *M. halterata*, hypandrium. Pr, proctiger; Ep, epandrium; Hp, hypandrium.



munication). Hussey (1961) presented data on the biology and immature stages of *M. bovista*.

There have been several reports of *M. bovista* infesting cultivated mushrooms in the U.S. Snetsinger (1972) reported *M. bovista* as the most common phorid in Pennsylvania mushroom houses. A review of the voucher material reported on by Snetsinger indicated that *M. halterata* was the phorid actually observed.

Megaselia (Megaselia) halterata (Wood)
(Figs. 4, 5)

Synonymy: *Megaselia (M.) plurispinosa* (Zetterstedt) Moreton, 1954; Colyer, 1956; *Megaselia (M.) dakotensis* Borgmeier, 1966; Norton and Ide, 1974; *Megaselia (M.) agarici* (Lintner) Weigel et al., 1959; *Megaselia (M.) bovista* (Gimmerthal), Kline, 1971.

Diagnosis.—This species can be distinguished from other North American *Megaselia* by the combination: Mesanepisternum bare; scutellum with 2 strong bristles; costa about 0.37% of wing length; halteres yellow. Hypopygium with epandrium (Fig. 4) with 2–3 strong bristles laterally on right; hypandrium (Fig. 5) with left lobe reduced to a thorn-like process. Oviscapt with sternum 6 absent.

Known Distribution.—Europe, North America.

Larval Biology.—The larvae feed primarily on mushroom mycelium.

Remarks.—*Megaselia halterata* is the dominant and the most important phorid pest of cultivated mushrooms in western Europe and the U.S. Broekhuizen (1938) first reported it associated with fungi. Hussey (1961), Hussey and Gurney (1964) and Kline (1971) presented data on the biology and immature stages. Colyer (1956) and Robinson (1975) reviewed the taxonomy.

This species was first recognized as a pest of cultivated mushrooms in western Europe in 1953. In the latter part of that year the number of *M. halterata* in English mushroom houses increased and the infestation spread in epidemic proportions. This outbreak apparently dislodged *M. nigra* and established *M. halterata* as the dominant pest in Europe.

Megaselia halterata was first reported from the U.S. in 1975. Information on museum specimens indicated that this species may have been present in North America since about 1906.

Megaselia (Megaselia) agarici (Lintner)
(Figs. 8, 9, 11)

Synonymy: *Phora agarici* Lintner, 1895; *Megaselia (M.) bovista* (Gimmerthal) Borgmeier, 1966; Snetsinger, 1972; Girard et al., 1972.

Diagnosis.—This species can be distinguished from other North Ameri-

can *Megaselia* by the combination: Mesanepisternum bare; scutellum with 2 strong bristles; costa about 0.38% of wing length; halteres yellow. Hypopygium with epandrium (Fig. 8) lacking strong bristles, pale; unarticulated process extends beneath proctiger; hypandrium (Fig. 9) with left lobe narrowed apically. Oviscapt with sternum 6 (Fig. 11) capitate, with 4 bristles.

Known Distribution.—North America.

Larval Biology.—The larvae feed on mushroom mycelium, stems, and caps.

Remarks.—*Megaselia agarici* was originally described as a pest of cultivated mushrooms in the U.S. (Lintner, 1895). Although widespread in the U.S., it has never been reported from western Europe.

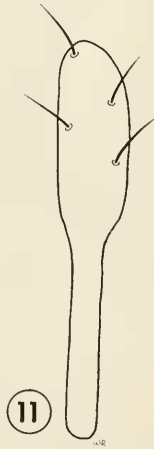
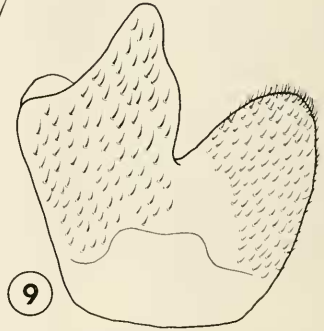
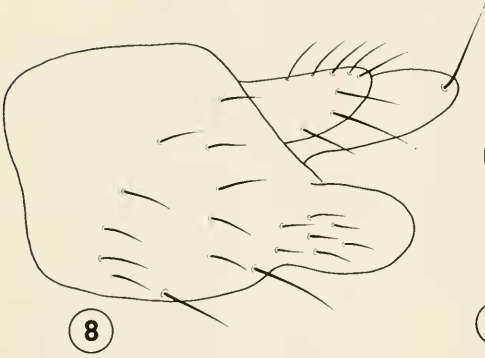
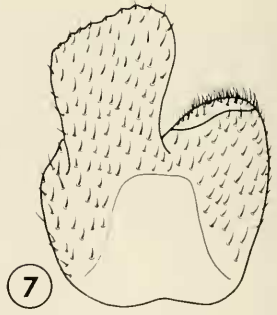
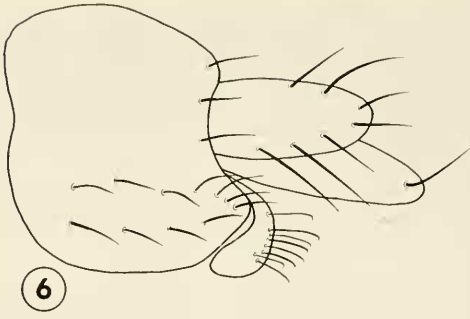
This species is usually considered the most important phorid pest of cultivated mushrooms in the U.S. However, it may not be as widespread or as important as previously thought. Although *M. agarici* was described as a pest of mushrooms in 1895, it was not reported again as a pest until 1934. Even in Thomas' (1942) paper *M. agarici* was not emphasized as an important pest. *Megaselia nigra* was treated as an equal, if not a more important pest at that time. *Megaselia bovista* does not occur in the U.S.

Megaselia agarici followed *M. nigra* in the succession of phorid pests in North American mushroom farms. This species was distributed in the major centers of mushroom production, such as the Kennett Square area in Pennsylvania and the area south of Albany, New York in the Hudson River Valley. Mushroom production in the New York location has greatly diminished in the last 15 years. This resulted in the disappearance of *M. agarici* in the remaining mushroom houses, and an absence of *M. halterata*.

Megaselia agarici has encountered some taxonomic problems. Lintner described *M. agarici* from many specimens and did not designate a holotype. A lectotype was selected by Robinson (1975) from 22 adults in the collection at the New York State Museum and Science Service. Borgmeier (1966) did not examine any of the original *M. agarici* material when he prepared his revision of the North American Phoridae. In the course of revising *Megaselia* he "provisionally" (but in fact) synonymized *M. agarici* with *M. bovista*. A year later, with the help of C. H. Colyer, Borgmeier (1967) stated *M. agarici* was indeed a valid species. Many workers were unaware that Borgmeier had changed his mind on the synonymy of *M. agarici*. Consequently, there are a few published reports that cite *M. bovista* as a pest of mushrooms in the U.S. (Girard, et al., 1972; Snetsinger, 1972).

Megaselia (M.) pygmaea (Zett.)

This species was reported as a pest of cultivated mushrooms by Thomas (1931). Since this phorid is not known to occur in the U.S. and voucher



specimens are not available, this record probably represents a misdetermination.

Megaselia (M.) longipennis (Malloch)

This species was reported [as *M. flavinervis* (Malloch)] as a pest by Thomas (1942). But there is no evidence that it was present in economically-important numbers. *Megaselia longipennis* has been reported feeding on a variety of materials (Robinson, 1971) and is probably not restricted to feeding on mushrooms.

Megaselia (M.) iroquoiana (Malloch)

This species was reported as a pest by Davis (1938) and Thomas (1942). There is no evidence it was present in economically-important numbers. *Megaselia iroquoiana* has been reared from dead insects (Weise, 1916) and is probably not restricted to feeding on mushrooms.

Results and Discussion

The commercial mushroom industry in the U.S. (and western Europe) has experienced several different *Megaselia* species as pests. At least three species (*M. nigra*, *M. agarici* and *M. halterata*) have been present in numbers high enough to cause economic damage to the crop. *Megaselia nigra* was a pest during the early period of mushroom production in the U.S. But improved growing methods eliminated it as a pest, only to allow *M. agarici* to emerge as the dominant pest. Within the past 10–15 years *M. halterata* has replaced *M. agarici*.

Two phorid pests (*M. nigra* and *M. halterata*) of commercial mushrooms in the U.S. were apparently introduced from western Europe. Hussey (1973) suggested that the importation of old-style mushroom spawns may have led to the introduction into the U.S. of pest species from European mushroom farms. *Megaselia halterata* has probably been in the U.S. for many years. Apparently, only recently have the conditions in U.S. mushroom houses been conducive for the increase in numbers of this phorid. When and how *M. halterata* replaced *M. agarici* are not known. It is interesting to note that while *M. nigra* and *M. halterata* were successfully introduced into the U.S., *M. agarici* has apparently not been introduced into western Europe.

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Figs. 6–11. *Megaselia* spp. 6, *M. bovista*, epandrium. 7, *M. bovista*, hypandrium. 8, *M. agarici*, epandrium. 9, *M. agarici*, hypandrium. 10, *M. nigra* female, sternum 6. 11, *M. agarici* female, sternum 6.

The history of phorid pests of commercial mushrooms in the U.S. shows that rarely is one species dominant for a very long time. The current species, *M. halterata*, may eventually be supplanted by another native or introduced species. Schmitz (1948) reviewed the records of several phorid genera with species known to be associated with fungi. Robinson (1971) listed more than 30 *Megaselia* species known to feed on fungi.

The mushroom industry has spread from the traditional centers in western Europe and the U.S. to new areas in the Far East. As the commercial mushroom industry spreads to new zoogeographic regions there is the threat of immigrations and emigrations of phorid pests. Hussey (1973) warned that future changes in commercial mushroom production methods, or the culture of other species of fungi, may lead to changes in the relative importance of pest species, or may mean species of pests new to the mushroom industry.

Phorid flies will probably always be a serious pest of cultivated mushrooms, wherever they are grown. Their importance will remain constant, but the pest species may change. Before effective control measures can be implemented, the pest must be accurately identified. Mushroom growers around the world should be alert to new outbreaks or unusual infestations of phorid pests. Phorids should be sampled periodically and voucher specimens submitted for identification.

Acknowledgments

I am grateful for the help provided by Drs. John McDaniel, Department of Entomology, University of Delaware; K. R. Valley, Pennsylvania Department of Agriculture; W. W. Wirth, Systematic Entomology Laboratory, IIBIII, Agric. Res. Serv. USDA; and W. Cantelo, Vegetable Laboratory, USDA. Mr. E. Binns, Glasshouse Crops Research Institute, England provided valuable information and specimens. Dr. K. G. V. Smith, British Museum (Natural History) was kind enough to loan important specimens. This work was supported in part by a USDA/ARS Cooperative Agreement with the Insect Identification and Beneficial Insect Introduction Institute, BARC. Dr. W. W. Wirth and Dr. W. Cantelo reviewed and improved the manuscript.

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